

## **Flow Accelerated Corrosion (FAC) and Tritium**

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**Directions: Read the following story and answer the comprehension questions at the end.**

Recently, a neighbor of ours called and asked my husband, James, if he knew anything about plumbing. Our neighbor had some water leaks in a bathroom shower and elsewhere. My husband laughed to himself and answered, “Yes, I know a little about plumbing.” The reason he laughed is because the primary function of a pressurized water reactor is to heat water using nuclear fuel which turns other clean water into steam which turns a turbine generator and produces electricity. After working 27 years at a nuclear power plant; fixing household plumbing leaks is no problem for my husband. He did a significant amount of work with pumps, valves, hoses, and leaks; including work that involved radioactively contaminated water during the years he spent in the Operations Department at the San Onofre Nuclear Generating Station. In other words, the entire primary and secondary systems at San Onofre consists of plumbing; so much plumbing that if an average person was to go into the belly of the power plant it would baffle their mind just looking at all the piping which goes everywhere and in every direction according to what my husband told me. Currently, the two remaining nuclear reactors at San Onofre have been permanently shut down due to poorly redesigned replacement steam generators that resulted in a tube leak which released radioactive steam to the environment on January 31<sup>st</sup>, 2012. The extensive amount of steam generator tube wear that was discovered after further investigation had never been seen before in the nuclear power industry at any other plant.

My husband set up a time to go to the house and look at the shower leak. The lady said her husband had recently replaced the hot and cold water valves, so she did not understand why they had started to leak again. My husband took apart both valves and noticed that the parts had unusual wear patterns, which were not from normal use. He knew from experience that the unusual wear was most likely from flow accelerated corrosion. The way that flow accelerated corrosion works in residential and agricultural applications is if a pin hole leak develops in a pressurized water system; the back pressure can be powerful enough to cause the stream of water to corrode away solid materials like metal, or concrete. So once the leak begins it will only get worse over time as the hole gets bigger, and more material is worn away.

Being the perfectionist that he is, my husband went looking for the root cause of the flow accelerated corrosion. James eventually discovered that the pressure regulator for the house was improperly adjusted and the water pressure was more than twice what it should have been. We normally keep the water pressure of our house at 65 psi (pounds per square inch). The water pressure at the neighbor’s house was 150 psi. The higher the water pressure, the stronger your pipes, connections, fittings, and valves have to be to withstand the force of the flowing water.

Nuclear reactor vessels are designed to withstand pressures up to 2500 psi; however, the normal operating pressure of the Unit 2 and 3 reactors at San Onofre was around 2250 psi. By doing a little mental arithmetic, you can see how forceful the flow of water through the primary

system at a nuclear power plant is compared to the flow rate in your own home or from your garden hose.

What was happening at our neighbor house is that several plumbers had fixed leaks without fixing the root cause of the leaks which was the misadjusted pressure regulator. The higher water pressure was putting significantly more stress and strain on all the pipes and valves eventually causing leaks and abnormal wear from flow accelerated corrosion.

**Questions:**

1. What percentage of pressurized water reactors (PWR) in the United States experience flow accelerated corrosion problems in their steam generators and other operating systems?
  - a. 25%
  - b. 50%
  - c. 75%
  - d. 100%
  
2. What percentage of boiling water reactors (BWR) experience flow accelerated corrosion in their operating systems?
  - a. 25%
  - b. 50%
  - c. 75%
  - d. 100%

The correct answer for both questions is d. 100%. Flow accelerated corrosion is a phenomenon which occurs wherever there is pressurized water and/or steam; especially high flow velocity water or steam.

This is how the International Atomic Energy Agency (IAEA) describes Flow Accelerated Corrosion:

*Flow-accelerated corrosion is wall thinning of steel piping due to turbulent and fast flowing water or wet steam that wears away the protective film (oxide layer) and leads to continued corrosion of the underlying metal. FAC is a chemical effect that is primarily influenced by pH, hydrodynamics, oxygen, and temperature. The geometric aspects of the system design and piping layout play a big role in the occurrence of FAC. Wall thinning in piping and vessels because of FAC has caused sudden ruptures in high and moderate energy systems, resulting in plant transients and affecting safety/non safety related equipment by leaking steam and water and risking personnel safety.*

*All reactor types have experienced some type of FAC related events in their piping systems. Many utilities have started the analysis of pipe wall thinning phenomenon using the available large amount of measurement data from operating plants. Plants have had FAC campaigns implemented for many years, and even with a mature and established FAC approach, events continue to occur.*

The source of the above quote: <http://www.iaea.org/NuclearPower/Engineering/CRP/FAC/>

According to what my husband was taught while working at the San Onofre Nuclear Generating Station; the plant was supposed to be a “zero leak” facility. In fact, all nuclear power plants are supposed to be “zero leak” facilities. However, the U.S. Nuclear Regulatory Commission (NRC) knows that there have been substantial leaks of contaminated water at commercial nuclear sites in the country but they continue to allow these reactors to operate. Many of the leaks that occur at nuclear power plants are caused by flow accelerated corrosion in the operating systems, or in buried or underground piping. Other leak sources are from valves, tanks, the evaporation of liquids, and the result of routine and approved releases. You can search the NRC website and find pages and pages of information about “leaks and spills” from buried piping, as well as, a list of 45 nuclear power plant sites leaking tritium, and tritiated water. Tritium, an isotope of hydrogen, has a chemical nature just like water, and when it is detected it often indicates the presence of more powerful radioactive isotopes that are often spilled at the same time: Cobalt-60, Cobalt-58, Cesium-134, Cesium-137, Strontium-90, and Nickel-63. Tritiated water, not to be confused with heavy water/deuterium, is chemically identical to normal water and the tritium cannot be filtered out of the water. In August of 2006, groundwater containing 330,000 picocuries per liter (pCi/L) of tritium was discovered at San Onofre under Unit 1 during decommissioning. On the same list were several other nuclear reactor sites that have had groundwater samples with millions of picocuries per liter of tritium. The NRC claims that these leaks are not dangerous to public health, nor did any local drinking water supply exceed the allowable level for tritium specified in the EPA’s Safe Drinking Water Act; but we know this is not true.

Two reactor sites where cancer clusters developed after tritium leaked into the groundwater were highlighted in the documentary *Atomic States of America*: the Braidwood Nuclear Power Station in Braceville, Illinois, and the Brookhaven National Laboratory on Long Island, New York. Yet, there are many other aging nuclear facilities which are threatening public health because of corroded pipes leaking contaminants into the surrounding groundwater. The key point to understand is that when a leak occurs at a nuclear facility it can be substantial because of the high operating pressures and flow rates of the various systems. This means that a large volume of contaminated water can leak out before it is detected. Another key point to understand is that once radioactive contamination is released into the environment through a leak or spill; it is difficult to know exactly how much soaked into the ground or seeped into a larger body of water or where it goes and who it affects. The amount of released contaminants on the NRC’s website are really just estimates.

I have included some links to NRC documents about tritium and buried pipes at the end. The thing that disturbs me when I read through the publically available documents on the NRC website is that there is a certain attitude which comes out in the writing. It is an attitude that says, “We are aware of these problems, but we have formed a task force, and done evaluations, and established a monitoring procedure, and our resident inspectors have all been trained, which means we have everything under control, so trust us because nuclear power is safe!” Yet we know that if there is ever a Loss of Cooling Accident (LOCA), a station blackout, a fire, or some other type of catastrophic equipment failure, or a natural event at a nuclear power plant the NRC resident inspectors are not going to be able to do anything to stop it.

I highly recommend reading this article about Radioactive Tritium leaks found at 48 Nuke Sites.

Written by Jeff Donn for the Associated Press and NBC News:

<http://www.nbcnews.com/id/43475479/#.UpdiNCLTI9A>

See: <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html> for information on *Tritium, Radiation Protection Limits, and Drinking Water Standards*

Plants with licensed radioactive material in groundwater: The NRC has prepared a [list of reactor sites where tritium has been detected in ground moisture or groundwater](#) on facility property.

For more information about buried pipes see:

<http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/buried-pipes-fs.html>

### **Summary of Events Leading up to the Permanent Closure of San Onofre:**

When I think back over my husband’s career at SONGS and our marriage relationship, early on there were two factors that I did not fully comprehend. The first factor which I did not understand is that everything my husband knew about nuclear power he had learned while working in the Operations Department at San Onofre. The NRC sets the training requirements for all Reactor Operators (RO’s), but all of the information is taught from a distinctly pro-nuclear perspective. So unless a nuclear worker wants to verify that everything he or she is being taught is correct, and is doing their own research to evaluate the latest research, they may have an unbalanced view of nuclear safety issues. I believe the turning point for my husband came when he got out of the Operations Department and started interacting more with people who had worked or currently worked at other nuclear reactor sites, and began reading third party performance reports from the Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO). My husband’s view point on nuclear safety changed when he got to a career level where he attended meetings with senior management and he could observe with his own eyes that many of these people had incorrect attitudes and a flawed perspective of the seriousness of the situation at San Onofre. One example occurred in 2006 when my husband was working in the Nuclear Oversight Department. He attended a meeting

with senior plant managers and one topic being discussed that day was the latest INPO performance report. Towards the end of the meeting one manager angrily declared, “We are doing just fine! We don’t need to change how we do things!” I do not know why a nuclear organization would pay to be evaluated by a third party if senior managers were just going to deny and down play the results; but that is what was happening among some managers at San Onofre. There was a certain haughtiness that San Onofre did not need to adhere to the best industry practices being initiated by other nuclear organizations.

Ironically, what history has shown is that by 2006 SONGS was already in the process of making the worst decision they could about design changes to the internal structures of the Replacement Steam Generators that were going to be built by Mitsubishi Heavy Industries. The original steam generators manufactured by Combustion Engineering had a “stay cylinder” in the bottom which provided a tremendous amount of support to the internal tubing. For some reason the engineers working on the project decided that the new generators did not need a stay cylinder. My husband is not a nuclear engineer, so he had no way of knowing exactly what was going on with the Replacement Steam Generator (RSG) Project. What he did know is that there were many un-qualified people in key decision making positions at San Onofre. Either these un-qualified people lacked the management/personality skills needed to run their department correctly, or they lacked site specific RO experience to really understand how the plant worked as a whole, or they lacked both management and technical skills in a few extreme cases. What never fully came out in the media coverage of the Unit 3 Steam Generator tube leak in January 2012 were all the internal problems at San Onofre. During the years that the RSG Project was going on, right up until the last new steam generator was installed, there were significant management change outs, and the plant’s performance rating according to assessments done by INPO, WANO and the NRC had dropped like a rock. At the same time that the plant’s performance rating was plummeting, the number of worker allegations filed with the NRC was going up dramatically. I believe that all of these events that happened at San Onofre were interconnected. The thing to note is that I only know about the incidences that went on in the departments my husband worked in, but I am sure that the things he shared with me were just the tip of the iceberg.

The second factor, which is tied to the first, is that I did not understand the level and intensity of the professional peer-pressure my husband was under when he went to work each day. My husband grew up on Long Island, New York, and is a strong minded person, but I still believe that he was negatively affected by the corporate/management propaganda that existed at San Onofre. When my husband was a young RO, a Shift Manager who had previously worked at another nuclear facility that had an actual reactor meltdown came into the Control Room and told everyone that they would never earn as much if they ever left the Operations Department. He also said they would be instantly fired if they ever got out of the union and took a company job. My husband figured out that this particular Shift Manager had an extremely unfavorable reputation and certainly was not truthful about other career opportunities at SONGS. But there were other men who felt completely locked into the Operations Department when there were

hundreds of people earning higher salaries in other departments at San Onofre who held positions with lower technical skill requirements, less responsibility, and a better work schedule with holidays and weekends off. The most egregious dirty deed that was committed at San Onofre is they shafted their union operators over and over, multiple times from start to finish. The whole situation stunk of corruption in high places. However, the problem was not just that the operators did not receive the pay raises or advancement opportunities they deserved; it was also the way the operators were disenfranchised by the rest of the organization. In the end looking back, it appears that there never was a big picture, long term strategy for managing the organization to ensure that the right people, with the right qualifications, were in the correct positions to make competent decisions for the plant's future success. The lesson to be learned is that incompetent utilities should not be allowed to operate nuclear power plants.

Recently a former co-worker sent my husband an email stating that he was "disappointed and dismayed" to find my letter to California Governor Jerry Brown on Donna Gilmore's San Onofre Safety website and he wanted to know if my husband was motivated by "anger and vengeance." I thought to myself, if he is disappointed and dismayed to see my letter on Donna's website, he is going to have a heart attack if he does an internet search of my name and sees everywhere else it shows up. I found my letter in the NRC's archives. Obviously, someone thought the NRC needed to read it. Basically, back in 2010 my husband was just doing his job the way he was trained to do it, which was to document the violations he witnessed, many of which were willful. Anger and vengeance had nothing to do with it. It's called having personnel integrity. There is a serious double sided problem with nuclear power. Utilities want their workers to do their jobs correctly, but they do not want their workers filing allegations with the NRC about serious willful violations committed by their senior managers. Anyway, it was not my letter to the Governor, or the allegations my husband filed with the NRC which ultimately shut down San Onofre. It was the fact that the NRC was not given the real data about the nature of the Replacement Steam Generators, claiming they were "like-for-like" to avoid a lengthy and expensive regulatory examination process. Eliminating most of the NRC oversight resulted in the plant installing four incorrectly designed steam generators in their two reactor units at the cost of nearly a billion dollars. It was a billion dollar mistake which really shut down San Onofre.

The bottom line is that my husband is immensely happy that he never went back to work at San Onofre after leaving his job in the Nuclear Regulatory Affairs Licensing Department in 2010. It was the best thing that could have happened to him. At the time that my husband left his job he had been working on many technical documents, including the Updated Final Safety Analysis Report, commonly known as the UFSAR. James actually enjoys doing this type of technical writing, and I can only imagine that more than just a few other people in his department were probably a little upset when they were told to finish the massive project. I also firmly believe that if James had continued working at San Onofre for three more years the stress would have killed him. Interestingly, this particular former co-worker who wrote to my husband never refuted the technical information in my letter to Governor Brown. He was merely upset that I stated that the health and safety of the public would be at risk if the NRC approved SCE's Unit 2

restart plan. He claimed that only the workers at the plant would have been in danger. Frankly, I do not think it is an acceptable practice to put nuclear workers at risk by continuing to operate damaged equipment and I did state that in my letter. I guess it is easier to attack a whistle blowing straw man than it is for a nuclear organization to accept responsibility for their own failures.

I have one last thought to conclude with. When I see someone gushing about the benefits of nuclear power I automatically think they are either ignorant of the economic realities of nuclear power, they are ignorant of the inherent dangers, or they are a paid advocate for the industry. I think that many energy corporations bought into the whole “nuclear power is our future” propaganda only to discover after initial startup that nuclear power plants go over budget to build, are more expensive to maintain and repair. The cost of staffing a training department for their licensed reactor operators and other plant workers is higher than anyone expected because of increased NRC standards after the accident at Three Mile Island. Also, the number of work hours involved in fulfilling all of the regulatory requirements placed on plant operators by the NRC is significantly higher than anyone foresaw in the early years of nuclear power generation. Every new law and regulation that is passed can easily add tens of millions of dollars in extra cost per year. Finally, the cost of storing nuclear waste or building an Independent Spent Fuel Storage Installation (ISFSI) is higher because a long term geological repository has never been created by the Federal Government. Ultimately, the operating cost per megawatt ratio for nuclear power is bad for the ratepayers who are footing the bill for this expensive electricity. Perhaps the best thing we can hope for at this time is that the NRC will create a San Onofre Lessons Learned Task Force to establish stricter criteria for safety related equipment replacement projects and an evaluation process for identifying a nuclear organization in crisis. However, it is going to take a tremendous amount of public pressure to get the NRC to be honest and do something about the inherent dangers that nuclear facilities pose to public health and safety. It would also help if more nuclear workers had the personal integrity, and boldness to step forward and report the safety violations they witness to NRC resident inspectors. Unfortunately, the fear of retaliation is very real within the nuclear power industry.

Letter to Governor Brown:

<http://sanonofresafety.org/2013/05/15/letter-from-wife-of-san-onofre-nuclear-operator-to-governor-brown/>

My letter can also be viewed on Ace Hoffman’s Animated Software page:

<http://www.animatedsoftware.com/environm/onofre/2013/SONGS%20letter%20~%20Gov.%20Brown%202Rev%20A.pdf>.