

## Joosten, Sandy

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**From:** Ace Hoffman <rhoffman@animatedsoftware.com>  
**Sent:** Sunday, June 15, 2014 6:24 PM  
**Subject:** A hare's breath from disaster: Who should pay for San Onofre's steam generator failure?

June 15th, 2014

Dear Readers,

Southern California Edison (SCE) wants permission to collect an additional \$3.3 billion from ratepayers -- hundreds of dollars each -- to cover costs and lost revenue from the San Onofre nuclear power plant, which will never operate again. The plant was shut down on January 31st, 2012 because of a "small" radioactive leak, and declared permanently inoperable by the owners on June 7th, 2013, just over a year ago.

Negligent engineering mistakes were made which gravely threatened the public. So why should the public have to pay for having had their lives, livelihoods, homes and families endangered? Additionally, a grotesque cover-up has been orchestrated to try to make sure the public doesn't figure out what really happened -- and how close we came to a nuclear catastrophe in southern California.

When a large power plant under oversight of the California Public Utilities Commission (CPUC) stops functioning before the end of its licensed operating period, if the outage lasts more than nine months the CPUC has mandated that it shall conduct an investigation, known as an OII (Order Instituting Investigation). The OII for San Onofre was divided into three phases. The order of the three phases is very odd.

The first phase of the OII was completed in 2013. Its purpose was to get a general understanding of why the reactor was shut down and what the economic impacts are.

The second phase, which is currently nearly completed, is to determine who should pay. Recently it was announced that a deal had been made between some of the parties in the OII proceedings. The "deal" sticks ratepayers with \$3.3 billion in additional charges.

The third phase of the OII was supposed to determine responsibility. Surely the third phase should have come before the second. But instead the CPUC announced that the third phase isn't necessary and won't happen, because of the agreement reached in phase two.

When the steam generator replacement project was first presented a decade ago, the CPUC and the public were told that it would save ratepayers over a billion dollars versus shutting the reactors down. Instead, southern California was nearly wiped off the map -- just like the areas around Fukushima and Chernobyl have been. We came "that close." A hare's breath from disaster.

Mitsubishi Heavy Industries (MHI) designed and fabricated the replacement steam generators. SCE approved the faulty designs. SCE also purposefully and successfully avoided public and federal regulators' scrutiny of the new designs by claiming they were "like-for-like" matches with the old designs, when in fact they were very different. A few weeks before the radioactive leak, SCE's and MHI's engineers had an article published in a technical journal where they bragged about their new steam generator's design, and even specifically about the regulatory hurdles they had squeezed past.

The Nuclear Regulatory Commission (NRC) states that SCE is responsible for the quality of the work of their subcontractors. But the NRC is responsible for the quality of the work of their licensees -- that's what they're there for. For that reason, San Onofre's failure can and should be blamed almost entirely on the NRC, even despite SCE's best efforts to hoodwink them. NRC should have seen through it. NRC "experts" had approved

dozens of prior steam generator replacement projects, and the NRC had ample opportunity to know that this project needed proper oversight, both by them and by the public.

To give you some idea of how arcane the regulations are, a "like-for-like" change can -- and often does -- include TWO changes which the utility determines balance each other out. An increased risk to the public due to one of the changes is supposedly compensated for by a decreased risk to the public in the other change. So for example, if the utility changes the alloy used in a part to a "stronger" metal (as was claimed for this project), they can then use less (thinner) tubing (which they also did) and still say it was a "like-for-like" replacement. At San Onofre, there were more than a dozen such changes between the old and the new steam generators, with essentially no NRC oversight because of the claim that the replacement steam generators were, nevertheless, "like-for-like" replacements.

The CPUC also had the responsibility of determining if SCE's claims regarding the replacement steam generators were accurate. Besides the asserted financial savings, the CPUC could have -- and should have -- questioned the safety of the project, including what would be done with the additional radioactive spent fuel that would be generated if the plant was allowed to continue operating. Although the NRC claims to have sole authority over nuclear safety, the CPUC claims they are mandated to provide "safe energy" to the public, so they have every right -- and a responsibility -- to concern themselves with the dangers of nuclear power. They must stop abdicating that responsibility.

SCE has wasted a lot of money. When ratepayers first started to be informed of SCE's steam generator replacement project, many activists said that SCE should be required to shut the plant down instead. Tube wear in the old steam generators was causing leaks of radioactive primary coolant and forced outages. Tube wear was so constant that SCE made predictions as to the exact year and month that each of their two reactors would reach a critical amount of wear, where even the lap-dog federal oversight agency, the NRC, would require them to shut down.

That day was to come about eight years before their reactor licenses would run out. This worked out well for SCE politically, because they claimed to the CPUC that a new set of replacement steam generators would let them operate not only through the rest of the license period, but through another 20-year extension beyond that, and maybe even another. 60 years was mentioned as the "possible" life of the new steam generators.

Steam generators are the largest components in a nuclear reactor, representing approximately 50% of the primary coolant loop barrier, and second in weight only to the reactor pressure vessel. The whole replacement project was, in actuality, a sneaky way to get around a California law that prohibits NEW reactors until a permanent national repository for the spent fuel has been created, which hasn't happened. So instead the reactor companies (PG&E and SCE) would just keep rebuilding their reactors, part by part by part. (PG&E still does this at Diablo Canyon.)

SCE got approval for the steam generator replacement project. But instead of lasting 60 years, the replacement steam generators lasted 22 months in Unit 2, and only 11 months in Unit 3.

The possibility of steam generator vibration problems like those that actually occurred at San Onofre were first documented in the 1970s. Due diligence on the part of the design engineers working on the replacement steam generators should have uncovered the errors. If SCE had been required to release the details of the new designs prior to the project's approval, qualified outside engineers -- or anyone else -- would also have had a chance to uncover the problems.

Not that finding the problem during the design phase would have been easy. Steam generators are extremely complicated. The fault lay somewhere among terms like "recirculation ratio," "void fraction," "dry steam," "fluid elastic instability," "flow induced vibration," and "computer modeling," which can only do rough approximations of complex thermodynamics.

Each steam generator contains a bundle of nearly 10,000 finger-diameter tubes, each about 50 feet long and curved 180 degrees in the middle, like an upside-down U. Inside the tubes is fast-moving, hot (about 590

degrees Fahrenheit), high-pressure, highly-radioactive primary coolant from the reactor. Outside the tubes is water at a much lower pressure (about 1200 PSI less).

As the water rises around the tubes, a portion turns to steam. Any water that is left in the vapor is expelled using dryers and separators located above the tube bundle. That water is immediately recirculated back into the steam generator.

The "dry" steam goes up and out a large pipe to the turbine building, where it is used twice: Once to turn the high pressure portion of the turbine, and again to turn the low pressure portion of the turbine. Then the steam is turned back into liquid using a condenser and third coolant loop. Once condensed, the secondary loop water is fed back into the steam generators (two per reactor), where it combines with the water that was removed in the dryers and separators above the U-tubes.

If there is a leak of primary coolant into the secondary coolant loop, radioactive gases are released when the secondary coolant loop steam is condensed back into liquid. These gases were detected when the tube leaked at San Onofre on January 31, 2012, causing operators to shut down the reactor (after a few minutes of additional monitoring of water levels).

The leak occurred because an area near the top of the tube bundle (in the U-portion) got too dry (in other words, there was not enough water in the steam that was being generated). The tubes need to stay wet, which requires at least about 1% water in the steam. Water dampens vibration and aids in heat transfer from the hot primary coolant inside of the tubes to the secondary coolant loop outside the tubes. It's believed that a small portion of the tube bundle had only about 0.4% water in it (about 99.6% steam). The tubes in that area rattled and banged into each other until one of them leaked radioactive primary coolant.

It was very fortunate that ONLY one tube leaked. NRC regulations do not address the possibility of rupture of more than one tube. A multi-tube rupture becomes a serious problem if there is a Main Steam Line Break (MSLB) at the same time, and a valve failure prevents the reactor operators from isolating the affected steam generator. In that case, primary coolant flowing out the leaking tubes will go directly to the outside environment with no way to stop it. It would be as if the reactor had a hole in the reactor pressure vessel itself.

But even if an MSLB and an isolation valve failure occurs, if only one tube leaks, the reactor operators can (theoretically) continue to replenish the primary coolant while they insert the reactor's control rods, maintaining circulation long enough to cool the reactor sufficiently to avoid a meltdown.

At San Onofre, besides the tube that leaked, two additional tubes in Unit 3 had more than 99% wall thickness worn away when the first tube broke. The tube walls are only about as thick as a credit card, so having only 1% left is literally less than paper-thin protection. In fact, in subsequent pressure testing, 8 tubes leaked at or below design basis levels (which is about three times normal operating pressure, to account for surges, inaccurate measurements, and other anomalies). Normal operating pressure of the primary loop -- inside the tubes -- is about 2200 PSI. Normally the secondary coolant loop -- the outside of the tubes -- is at about 1000 PSI. But during a Main Steam Line Break, the outside the tubes would only be at atmospheric pressure. So in a "design basis accident" (which the utility is required to plan for, and which includes an MSLB with an isolation valve failure), the failure of multiple tubes would have put San Onofre outside their legal operating parameters. There would have been no training in what to do, no instructions to follow, no pages to turn to in the manuals, and no experts to call with prior experience or knowledge.

So we almost lost southern California. And we never needed to be put at this risk at all, because ten years ago, the decision to install these replacement steam generators could have included a public forum where numerous reasonable objections could have been made, which might have stopped the project entirely right then and there.

To everyone's benefit.

After all, SCE was only claiming that by spending the \$670 million, which could have been spent on renewable resources instead, ratepayers were going to save a billion dollars over the next 20 years. They did not tell

ratepayers that instead they might have to pay \$3.3 billion, plus the \$670 million, plus another billion dollars in other upgrades that would never have been done if the units were being retired as the first steam generators reached their life expectancy (such as a reactor pressure vessel head replacement). Some of the wasted money was for the year and a half that San Onofre's owners thought maybe they could restart Unit 2. SCE kept over a thousand extra employees on staff.

Nearly everyone understood by spring of 2012 that Unit 3, the Unit that leaked, would never reopen, and it was defueled as soon as practical. But Unit 2, some thought, had a possibility of restart, at reduced power, in some sort of "experimental" phase or test which was to last only 5 months. A normal operating cycle was 22 months, and cracks tend to propagate exponentially over time. The utility consistently denied it was an experiment, because experimenting with the lives of eight million people living within 50 miles of the reactor is not reasonable or legal. But that's what it would have been.

Nobody knew why the tube bundles in the steam generators in Unit 3 experienced the dry-out phenomenon and accompanying vibrations and tube-to-tube wear (the phenomenon is known as Fluid Elastic Instability (FEI)). But SCE was certain that despite other excessive wear from flow-induced vibration in the Unit 2 tube bundle, FEI had not occurred. So SCE wanted to restart Unit 2.

But the utility had already promised not to restart either reactor until the "root cause" of the problem in Unit 3 was discovered. The NRC had also promised to produce a "thorough" report (known as an Augmented Inspection Team (AIT) report).

This dollop of generosity to the safety of the public was not due to anything other than that the utility and the NRC had all been caught asleep at the switch: Unit 2, fortunately, was shut down for refueling when Unit 3 sprung a leak, but, despite spending \$670 million dollars to replace the steam generators, the utility did not take the opportunity to look very closely at the wear and tear of the tubes in Unit 2 until after Unit 3 leaked. They didn't look, even though extensive tube wear in the original steam generators was what caused the replacement project in the first place, and these were supposedly "like-for-like" replacements!

After Unit 3 shut down, a closer inspection of its sister unit revealed extensive premature wear to the tubes in Unit 2's steam generators, but not of the type that caused Unit 3's tubes leak.

Despite numerous promises of an open process, the public has never been able to know precisely what caused Unit 3 to rattle as much as it did, or Unit 2 to rattle less, but still an unprecedented amount. Many documents have been released, but key values have been redacted. It is clear that everybody involved overlooked the possibility of a phenomenon known as "in-plane vibration." Additionally, SCE purposefully avoided regulatory and public scrutiny, and the regulators purposefully looked the other way. All that's missing is the names of the perpetrators of these crimes, and that seems to be fine with all the regulatory agencies.

California's regulatory agencies assumed on faith that the steam generators would work as designed because the NRC had approved them. Now that they didn't work, the CPUC doesn't want to bother assigning blame, and wants to let SCE bill the ratepayers for nearly 100% of the financial burden from the failure. The NRC doesn't want to accept ANY blame, simply claiming it reviewed the documents it was given by SCE appropriately. But the NRC could easily have detected that the new steam generators were substantially NOT "like-for-like" and asked for more information and a public hearing. Instead the NRC allowed SCE to avoid the lengthy "10 CFR 50.90" license review process (which would have included public hearings), in favor of a simpler "10 CFR 50.59" filing claiming the new steam generators were a "like-for-like" replacement for the old ones.

When the CPUC finally decided to do an OII -- not for safety reasons, but because the plant wasn't "used and useful" nine months after it was shut down -- they quietly hired "experts" to advise the CPUC judges assigned to the investigation about the details of how steam generators function within a nuclear reactor. These experts were paid out of SCE funds and had access to SCE documents and personnel -- providing SCE felt like giving them the documents and letting their employees talk to them! Room for bias? Plenty. This bias was probably why the president of the commission, Michael Peevey, had a bit of a meltdown of his own, yelling at an

attorney representing ratepayers: "SHUT UP!" when asked about any "ex parte" communications he had had with the utility. "Lots" was the correct answer.

SCE doesn't want to admit that they demanded the impossible of MHI. They wanted improved performance from the new steam generators, even though they would be using a metal alloy with significantly lower heat transfer capabilities. At the same time they were claiming the new steam generator design was a "like-for-like" replacement for the old design. MHI thought they had figured out a workable design, but actually hadn't done their math calculations correctly. They had entered bad data into their programs, and gotten bad data back, and no one at SCE or MHI noticed. For example, the engineers thought the recirculation ratio of the water in the steam generators would be at least 4, meaning feedwater would enter the steam generator, rise up to the top, come out the "dryers and separators" above the tube bundle, then go around again, and again, an average of four times before exiting as "dry" steam. The actual recirculation ration turned out to be about three and a half.

So who's to blame?

According to the CPUC, the ratepayers are somehow at fault, and should pay another \$3.3 billion on top of everything they've already paid for this terrible idea. According to the NRC, Southern California Edison is at fault, and not the NRC. According to SCE, MHI is at fault, and they're suing MHI for hundreds of millions of dollars, despite the fact that SCE dictated nearly every aspect of the steam generator's design requirements, and SCE's engineers approved all the plans. SCE sent engineers to Kobe, Japan, where the steam generators were being designed and fabricated. SCE specifically demanded that special attention be given to vibration problems, which had plagued the first set of steam generators. SCE also demanded to be able to review all engineering drawings at any time, and to handle all interactions with the NRC.

SCE engineers, and outside engineers contracted by SCE, all signed off on MHI's design. MHI's liability appears limited by their contract with SCE to the actual replacement cost of the steam generators: \$130 million dollars. Transportation, disposal of the old steam generators (in a radioactive landfill), replacement energy costs, installation, and the cost of finding the "root cause" after the failure (or at least the half-hearted attempt that was made) were not included in MHI's liability.

The NRC was the most negligent of all. They could they have ensured that public hearings occurred prior to the project's start, so that citizens (and the NRC themselves) could have had access to the faulty design plans. The NRC could also -- right now -- demand that SCE produce the missing data that is vital to solving the puzzle of what actually went wrong.

NRC also, and most importantly, could have refused to give SCE permission to replace the steam generators at all until and unless a solution to the biggest problem with nuclear power was found -- the problem of what to do with the spent fuel that remains. The CPUC could have made the same demand. Activists tried to.

Right now nearly all of San Onofre's spent fuel still sits at San Onofre, vulnerable to tsunamis, earthquakes, terrorists, structural failure of the containment, and many other dangers. Right now, SCE plans to put the waste into dry casks as quickly as possible, then walk away, waiting until a national repository opens somewhere (in other words, until just after hell freezes over). One or two guards will be left to walk around the site a couple of times per shift. Their children's children's children's children -- I could go on -- will also be guarding the waste. The fuel could sit on the beach at San Onofre for hundreds of thousands of years.

San Onofre should have been shut down long ago -- it never should have opened. Now that it's closed, the ratepayers will have enough problems dealing with the spent fuel. They should not have to pay Edison for the negligent engineering that doomed their nuclear power plant.

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